Propagation Modeling

Amalia E. Barrios
SPAWARSYSCEN SAN DIEGO 2858
Atmospheric Propagation Branch
49170 Propagation Path
San Diego, CA 92152-7385
phone: (619) 553-1429 fax: (619) 553-1417 email: amalia.barrios@navy.mil

Dr. Richard Sprague
SPAWARSYSCEN SAN DIEGO 2858
Atmospheric Propagation Branch
49170 Propagation Path
San Diego, CA 92152-7385
phone: (619) 553-1420 fax: (619) 553-1417 email: richard.sprague@navy.mil

N0001403WX20540
http://sunspot.spawar.navy.mil/

LONG TERM GOALS

Develop electromagnetic propagation models for use in operational or engineering propagation assessment systems.

OBJECTIVES

Develop an advanced unified hybrid radio propagation model based on parabolic equation and ray-optics methods for both surface-based and airborne applications. This model is named the Advanced Propagation Model (APM) and is the model used in the Advanced Refractive Effects Prediction System (AREPS). Extend our modeling capabilities to HF frequencies below 100 MHz. Also develop an efficient method to estimate surface-based duct parameters from land clutter.

APPROACH

We develop parabolic equation, ray optics, waveguide, and other models as necessary to produce both accurate and efficient models to be used in propagation assessment systems. In many cases we can use variations of existing models to achieve this goal, but sometimes completely new models are necessary. Once developed, these models are compared to other models and to experimentally collected propagation data for verification of accuracy. We stay abreast of other researchers' newest models by reading current literature, participating in propagation workshops, and attending conferences as appropriate. There is a strong international exchange of ideas and techniques in this area, as some important work is performed outside of the USA. This ongoing project has developed a hybrid ray optics/parabolic equation propagation model for assessing the effects of the atmosphere and the environment in general on electromagnetic emissions in the range of approximately 100 MHz to 20 GHz for both surface based and airborne transmitters.

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There has been increasing interest in high frequency (HF, 2-30 MHz) propagation recently as a result of increased user demand for satellite time and the lack of available bandwidth for current systems, let alone those being developed for future deployment. HF offers an alternative to satellites for over-the-horizon long-haul communications when used in the sky-wave mode. In ground wave mode, ranges beyond line-of-sight are obtainable with good signal-to-noise ratio over ocean paths, even in rough sea states.

This project is divided into two tasks: (1) Refractivity From Land Clutter, PI Amalia Barrios, and (2) HF Propagation Modeling, PI Dr. Richard Sprague.

In support of the Refractivity Data Fusion and Assimilation (RDFA) project (PI Ted Rogers, SSC San Diego), we developed an algorithm to estimate surface-based duct parameters from land clutter. Our initial studies looked at two methods: 1) parabolic equation (PE) and 2) ray trace.

Our efforts at improving our HF modeling capability within the fleet this year have been in response to fleet request; we have implemented an HF ground wave predictive capability into APM.

WORK COMPLETED

REFRACTIVITY FROM LAND CLUTTER

Based on earlier work done by Ted Rogers, Jeff Krolik, and Peter Gerstoft [1-3] in estimating refractive parameters from sea clutter, a least-squares approach was initially developed using the split-step PE method in determining surface-based duct parameters from land clutter. A novel method was also developed using a ray trace and rank correlation scheme. This approach relies on ray tracing to determine the density of rays striking, or illuminating, the surface for a given refractive profile. The ray trace/rank correlation method was extensively tested in simulation and with real clutter observations.

HF PROPAGATION MODELING

The HF ground wave implementation is now largely complete. Still to be completed is the inclusion of available HF antenna patterns that we have begun with the help of personnel in SSC Code 2856. These patterns are obtained from brass-model measurements of U.S. Navy ships. Many of the ships currently active have been measured and the data will be used to improve our predictions. This is a large data-entry task and will be ongoing. The HF ground wave calculations are merged with sky-wave calculations from existing models and combined to produce estimates of total field where appropriate.

RESULTS

REFRACTIVITY FROM LAND CLUTTER

From simulations, the ray trace/rank correlation scheme proved to be more efficient and robust than the least-squares PE method. Also, the ray trace method provided reasonably good results when compared with surface clutter data taken from the Supplemental Weather Radar (SWR) located at SSC San Diego. The inclusion of height elevation information along the propagation path greatly decreased the ambiguity associated with estimation of refractivity parameters from surface clutter. Figure 1 below shows estimated profile results from the ray trace/rank correlation method using clutter data taken from the SWR on June 18, 2001. Clutter observations were taken over several groups of bearings that specifically included land along the path. Three groups consisting of several bearings were used over San Clemente island, Catalina island, and the Los Angeles area. The estimated surface-based duct parameters for each group of bearings were used to obtain the refractivity profiles shown on the right in Figure 1.

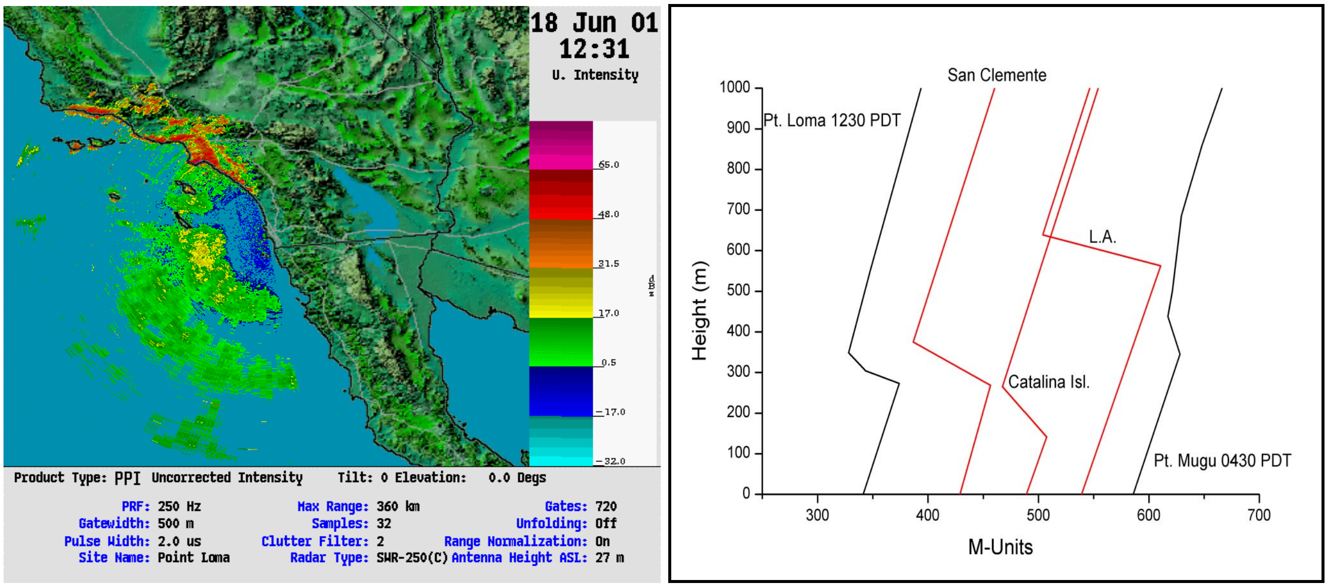

Figure 1. Clutter map from the SWR (left) and estimation results (right) from the ray trace/rank correlation method using surface clutter observations from the SWR over several groups of bearings – San Clemente, Catalina Island, and Los Angeles area.

HF PROPAGATION MODELING

The HF ground wave calculation in APM is largely complete, except for the inclusion of the updated antenna database as discussed above. The calculation is included for all frequencies less than 50 MHz. Due to the lack of a suitable database we are not able to compare prediction results to real data. However, standard accepted models of HF ground wave propagation exist and Figure 2 shows a comparison of the new APM model to a standard model developed by Berry (4). The figure compares predictions over sea-water for a flat ocean at 2, 10, 20 and 30 MHz. Comparison between the two models is quite good, with differences less than 5 dB for all frequencies and ranges, especially considering the completely different modeling approach used in the two programs. The 20 MHz APM curve in the figure shows the effect of a numerical instability at ranges between about 30-90 km for this case of large surface conductivity. We are currently working on identifying the source of the instability.

IMPACT/APPLICATIONS

The goal of this work is to produce an operational hybrid radio propagation model for incorporation into U.S. Navy assessment systems. Current plans call for APM to be the single model for all radio propagation applications. As APM is developed it will be properly documented for delivery to OAML, from which it will be available for incorporation into Navy assessment systems. The development of an efficient algorithm to estimate surface-based duct parameters from land clutter is in direct support of the RDFA project pursuing the concept of extracting refractivity profile information from radar clutter returns.

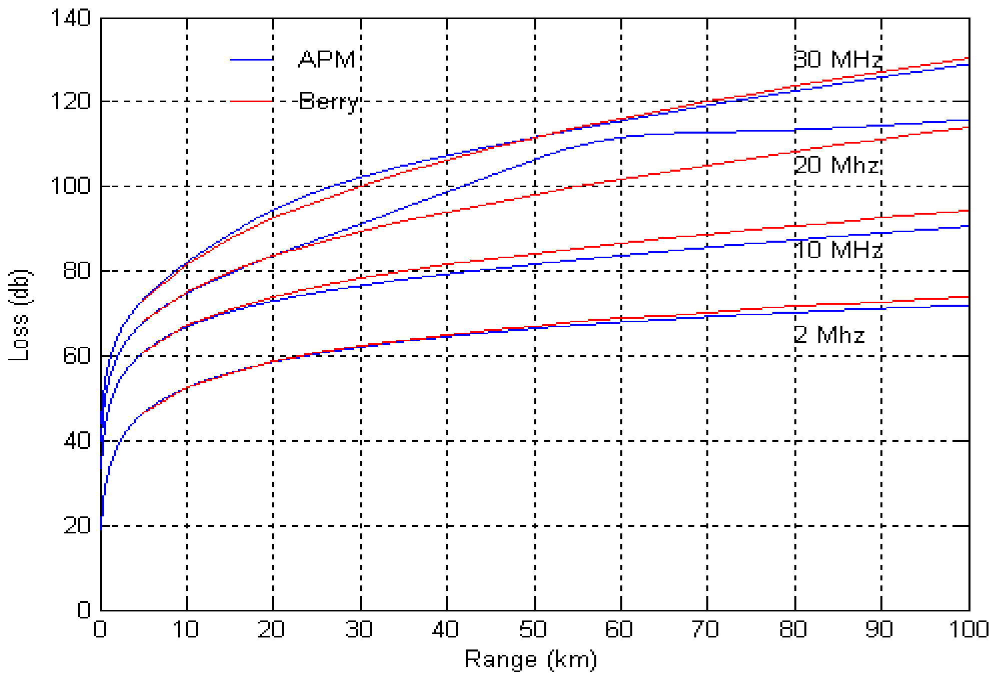

Figure 2. Comparison of APM ground wave model predictions to those of the Berry model. Loss values shown are those on the surface. Predictions are for a flat ocean and a vertically polarized wave field.

The growth of satellite communications and wide-band digital communications techniques over the last twenty years has led to a commensurate loss of HF capability and corporate knowledge. However, HF systems remain in everyday use within the fleet and require software tools to ensure their optimum performance. Our HF models are developed to provide these tools.

TRANSITIONS

All APM modifications and added capabilities transition into the Tactical EM/EO Propagation Models Project (PE 0603207N) under PMW 150 which has produced the Advanced Refractive Effects Prediction System (AREPS). Academia and other U.S. government are also utilizing APM/AREPS. APM is also currently being used by foreign agencies as the underlying propagation model within their own assessment software packages. APM is the current propagation model of choice for the Office of Naval Intelligence (ONI) sponsored program the Advanced Low Altitude Radar Model (ALARM).

RELATED PROJECTS

This project is closely related to the synoptic and mesoscale numerical analysis and prediction projects pursued by NRL Monterey. This project is also related to the Refractivity Data Fusion and Assimilation (RDFA) project under ONR 321SI in providing fast-running, high-fidelity forward propagation modeling used in the Refractivity from Clutter (RFC) inference techniques. The transition target for this project is the Tactical EM/EO Propagation Models task under PMW 150 and the

Oceanographic and Atmospheric Master Library. Tri service coordination is conducted under the Technology Area Review and Assessment.

The Combat Systems Baseline Plan from N76 (signed by RADM Balisle) calls for implementation of through-the-sensor (TTS) technology for generating refractivity assessments in Aegis baseline 7.1. SSC San Diego is the developer of TTS technology for radar systems under the RDFA project headed by Ted Rogers (Code 2858). The refractivity-from-land-clutter work performed under this task directly supports work done under the RDFA task.

REFERENCES

1. Gerstoft, P., D.F. Gingras, L.T. Rogers, and W.S. Hodgkiss, "Estimation of radio refractivity structure using matched field processing", IEEE Trans. Ant. & Prop., 48, 345-456, 2000.
2. Gerstoft, P., L.T. Rogers, and J.L. Krolik, "Inversion for refractivity parameters from radar sea clutter", submitted to Radio Sci., 2003.
3. Krolik, J.L., and J. Tabrikian, "Tropospheric refractivity estimation using radar clutter from the sea surface", in Proceedings of the 1997 Battlespace Atmospherics Conference, SPAWARSYSCEN Tech. Rep. 2989, 635-642, Space and Naval Warfare Systems Center, San Diego, Calif., March 1998.
4. Berry, D.E. and M.E. Chrisman, 'A Fortran program for calculation of ground wave propagation over homogeneous spherical earth for dipole antennas', *Rep. 9178,* National Bureau of Standards, Boulder, CO, 1966.

PUBLICATIONS

Barrios, A., "Estimation of Surface-Based Duct Parameters From Surface Clutter Using A Ray Trace Approach", submitted to Radio Science, July 2003.

Barrios, A., "A Ray Trace Approach For Estimation of Refractivity From Land Clutter", National Radio Science Meeting, URSI, 9-12 January 2002, p. 193.

HONORS/AWARDS/PRIZES

Amalia Barrios (SSC San Diego) received a Meritorious Team Commendation award from the Coast Guard for her participation in the planning, development and source selection for the Rescue 21 Phase II contract, the largest Information Technology acquisition in Coast Guard history. Her specific contribution was in using APM for environmental impact assessments and evaluating other propagation models that were being used by the respective bidders as part of their proposals for the Coast Guard contract.